MODIFICATION TO THE CDIO SYLLABUS: UPDATES AND EXPANSIONS TO INCLUDE LEADERSHIP AND ENTREPRENEURSHIP

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ABSTRACT

CDIO is a generalized model for the enhancement of engineering education. CDIO programs impart to the student a broad base of knowledge, skills, and attitudes necessary to become successful young engineers. This array of abilities is represented in the CDIO Syllabus. This paper examines the role of the Syllabus in the design of CDIO programs, and in meeting CDIO Standard 2. It compares the CDIO Syllabus with the UNESCO four pillars of learning, and finds them to be highly aligned. The Syllabus is then compared with the national accreditation and evaluation standards of several nations, and found to be consistent, but more detailed and comprehensive than any of the individual standards. Based on these comparisons, as well as other input received over the last decade, it is proposed that the CDIO Syllabus be modified, in part to add missing skills and in part to clarify labels, to make the Syllabus more explicit and more consistent with national standards. The result is called the *CDIO Syllabus, Version 2.0.* In modern society, engineers are increasingly expected to move to positions of leadership, and often take on an additional role as an entrepreneur. This paper also explores the degree to which the CDIO Syllabus already covers these topics, and the extensions that might be necessary to more adequately cover these two important roles of engineers. The CDIO Syllabus is compared with modern models of leadership and entrepreneurship, and extensions to the Syllabus are proposed. The proposed outcome is an extended version of the Syllabus, called the *CDIO+LE Syllabus*.

KEYWORDS

CDIO Syllabus, CDIO Standard 2, knowledge taxonomies, engineering leadership, entrepreneurship

INTRODUCTION

CDIO is a generalized model for enhancing engineering education. It moves engineering education from a model built on the abstractions of engineering science, toward one based on engineering science integrated into the context of practice. It responds to the needs expressed by program graduates, industry, governments, and national accreditation and evaluation bodies around the world.

These needs have been expressed in many ways. We summarize it by stating that every graduating engineer should be able to: "Conceive-Design-Implement-Operate complex value-added engineering products, processes and systems in modern team-based environments." [1] CDIO explicitly prepares students to enter careers as effective members of engineering teams, and they should leave the university "Ready to Engineer."

The CDIO approach strives to prepare students with the knowledge, skills and attitudes to be *leading engineers*. The approach has three overall goals: *To educate students who are able to:*

- *Master a deeper working knowledge of technical fundamentals*
- *Lead in the creation and operation of new products, processes, and systems*
- *Understand the importance and strategic impact of research and technological development on society* [1]

A CDIO education stresses the fundamentals, and is set in the *context* of conceiving, designing, implementing, and operating products, processes, and systems. We seek to develop programs that are educationally effective *and* more exciting to students, attracting them to engineering, retaining them in the program and in the profession.

One of the early and key documents developed by the CDIO Initiative was the CDIO Syllabus, which outlines the knowledge, skills and attributes expected of a graduating engineer. The objective of this paper is to review the CDIO Syllabus, nearly ten years after its drafting, for its applicability and continued relevance. We propose some minor changes in the document to increase its contemporary relevance and broaden its coverage.

Premises of the CDIO Approach

Three premises -- capturing the vision, goals, and pedagogical foundation -- are fundamental to the CDIO approach:

1. The underlying need is best met by setting goals that stress the fundamentals, while at the same time making the process of conceiving-designing-implementing-operating products, processes, and systems the *context* of engineering education
2. Learning outcomes for students should be set through stakeholder involvement, and met by constructing a sequence of integrated learning experiences, some of which are experiential, that is, they expose students to the situations that engineers encounter in their profession
3. Proper construction of these integrated learning activities will cause the activities to have dual impact, facilitating student learning of critical personal and interpersonal skills; and strengthening product, process, and system building skills, while simultaneously enhancing the learning of the fundamentals [1]

Premise #1

The need to make conceiving-designing-implementing-operating the context of engineering education is so fundamental to the CDIO approach that it is captured in the first CDIO Standard, or principle of effective practice.

Standard 1 – The Context Adoption of the principle that product, process, and system lifecycle development and deployment -- Conceiving-Designing-Implementing-Operating -- are the context for engineering education

A learning context is the set of cultural surroundings and environments that contribute to understanding, and in which knowledge and skills are learned. We believe that the product, process, or system lifecycle (conceiving-designing-implementing-operating), should be the *context*, but not the *content*, of engineering education. The setting of the education, the skills we teach, and the attitudes we convey should all indicate that conceiving-designing-implementing-operating is the role of engineers in their service to society. Note that the standard requires that engineering education should provide a general framework of product, process, and system lifecycle development and deployment, of which conceiving-designing-implementing-operating is an example. This idea was more fully developed in the keynote address of the 2008 CDIO International Conference. [2]

Premise #2

The second premise suggests setting learning outcomes that impart to the students the broad base of knowledge, skills, and attitudes necessary to be a successful young engineer. These are enumerated within the framework document entitled *CDIO Syllabus – A Statement of Goals for Undergraduate Engineering Education*. [3] The *CDIO Syllabus* was developed through discussions with focus groups comprised of various stakeholders, and by reference to other documentation of the time. As shown in Table 1, the CDIO Syllabus classifies learning outcomes into four high-level categories: technical knowledge, personal attributes, interpersonal skills, and the skills specific to the engineering profession. The content of each section was expanded in the CDIO Syllabus to a second level (also shown in Table 1), to a third level (see Appendix A), and to a fourth level (available at http://www.cdio.org). To ensure comprehensiveness, the Syllabus was explicitly correlated with key documents listing engineering education requirements and desired attributes. As a result of this development process, the CDIO Syllabus emerged in 2001 as a rational and consistent set of skills, derived from an understanding of needs, that stakeholders would expect from graduating students. We will call this version of the CDIO Syllabus developed and published in 2001 the *CDIO Syllabus Version 1.0*.

CDIO Syllabus v1.0 has proven to be a useful reference for those developing engineering programs, planning curricula, and evaluating student learning. It has now been translated into Swedish (see Appendix B), French (see Appendix C), Spanish (see Appendix D) and Chinese (see Appendix E). Of course, the CDIO Syllabus is just a reference document, and it is not prescriptive. If programs feel that the CDIO Syllabus is not appropriate for their programs, or needs to be expanded, they can modify it in any way desirable to them.

Table 1
CDIO Syllabus v. 1.0 at the Second Level of Detail

1 TECHNICAL KNOWLEDGE AND REASONING	**3 INTERPERSONAL SKILLS: TEAMWORK AND COMMUNICATION**
1.1 KNOWLEDGE OF UNDERLYING SCIENCE	3.1 MULTI-DISCIPLINARY TEAMWORK
1.1 CORE ENGINEERING FUNDAMENTAL KNOWLEDGE	3.2 COMMUNICATIONS
1.2 ADVANCED ENGINEERING FUNDAMENTAL KNOWLEDGE	3.3 COMMUNICATIONS IN FOREIGN LANGUAGES
2 PERSONAL AND PROFESSIONAL SKILLS AND ATTRIBUTES	**4 CONCEIVING, DESIGNING, IMPLEMENTING, AND OPERATING SYSTEMS IN THE ENTERPRISE AND SOCIETAL CONTEXT**
2.1 ENGINEERING REASONING AND PROBLEM SOLVING	4.1 EXTERNAL AND SOCIETAL CONTEXT
2.2 EXPERIMENTATION AND KNOWLEDGE DISCOVERY	4.2 ENTERPRISE AND BUSINESS CONTEXT
2.3 SYSTEM THINKING	4.3 CONCEIVING AND ENGINEERING SYSTEMS
2.4 PERSONAL SKILLS AND ATTITUDES	4.4 DESIGNING
2.5 PROFESSIONAL SKILLS AND ATTITUDES	4.5 IMPLEMENTING
	4.6 OPERATING

CDIO Standard 2 emphasizes the importance of setting a comprehensive set of learning outcomes, aided by the CDIO Syllabus. Note the Syllabus is named in the shorthand title for the Standard, but not in the text of the Standard; it is a reference, not a prescription.

STANDARD 2 -- CDIO SYLLABUS OUTCOMES
Specific, detailed learning outcomes for personal, interpersonal, and product, process and system building skills, consistent with program goals and validated by program stakeholders

An engineering program should set learning outcomes for the knowledge, skills, and attitudes intended as a result of engineering education. The CDIO Syllabus is intended as an aid in this process. Also a part of Standard 2 is that learning outcomes are reviewed and validated by key stakeholders, that is, groups who share an interest in the graduates of engineering programs, for consistency with program goals and relevance to engineering practice. In addition, stakeholders help to determine the expected levels of proficiency, or standards of achievement, for each learning outcome. [1]

Premise #3

Having discussed CDIO Standards 1 and 2 in some detail, it is worth mentioning the remaining ten CDIO Standards that are implicitly referenced in the third premise. These standards cover the effective practices that allow us to reach the learning outcomes (Standard 2) within the context of engineering practice (Standard 1). They include curriculum design (Standard 3), first-year engineering courses (Standard 4), design-implement experiences (Standard 5), learning workspaces (Standard 6), teaching and learning (Standards 7 and 8), the development of faculty competence (Standards 9 and 10), student learning assessment (Standard 11), and program evaluation (Standard 12). Further discussion of these effective practices and examples of their implementation within CDIO programs is provided in *Rethinking Engineering Education: The CDIO Approach*. [1]

Objective of This Paper

With this background, the specific objective of this paper is to review the content and applicability of the CDIO Syllabus ten years after its drafting, and recommend updates and evolution. Discussion touches on the following points:

- The historical development of the CDIO Syllabus
- The use of the Syllabus in aligning curriculum, teaching and learning, and assessment
- Proposed modifications in the core Syllabus to respond to broad-based input
- Proposed extension of the Syllabus to include entrepreneurship and leadership

THE DEVELOPMENT OF THE CDIO SYLLABUS

The CDIO approach has its origins in an attempt to understand the needs of industry, and use them to inform the design of engineering education. Over a period of about one year, interviews and focus groups were conducted with engineering faculty, students, industry representatives, university review committees, alumni, and senior academics. The focus groups were asked, "*What is the full set of knowledge, skills, and attitudes that engineering students should possess as they leave university?"* We then sought to organize these outcomes in such a way that it would be easy to adapt to the needs of a local program and engineering disciplinary field, while explicitly recognizing the skills and abilities that are common to all engineers, and the specific characteristic of a CDIO-based education, that is, to be firmly rooted in the Conceive-Design-Implement-Operate context.

Organization of the CDIO Syllabus

Results of the focus groups and topics extracted from reference documents were organized into a list that evolved into the CDIO Syllabus, which is shown at the second level of detail in Table 1. At the highest level of organization, the Syllabus is divided into four sections:

1. Technical knowledge and reasoning
2. Personal and professional skills and attributes
3. Interpersonal skills: teamwork and communication
4. Conceiving, designing, implementing, and operating systems in the enterprise and societal context

These four headings were arrived at by a logical clustering of the over one hundred topics that emerged from the interview process. The organization reflects cognitive knowledge, how to think, how to work with others, and how to engineer. It also maps directly to the underlying need identified above, that is, to educate students who can:

Understand how to conceive, design, implement, and operate (Section 4)
Complex value-added engineering products, processes, and systems (Section 1)
In modern team-based engineering environments (Section 3), and
Are mature and thoughtful individuals (Section 2). [1]

The last phrase, "are mature and thoughtful individuals," acknowledges that within a university context, students grow psychologically and socially, as well as intellectually. The first section, *Technical Knowledge and Reasoning*, is program-specific, that is, it outlines major concepts of a specific engineering discipline. Sections 2, 3, and 4 are applicable to any engineering program.

Alignment of the CDIO Syllabus

The first draft of the Syllabus was compared with existing lists of criteria and standards, including ABET 2000 [4], and lists provided by several professional societies and corporations. In all cases, the CDIO Syllabus was found to be more comprehensive. The document was also peer reviewed by specialists in the many fields represented, for example, communications, ethics, system thinking, in order to ensure that the document would be consistent with the organization of knowledge used by professionals in the various fields.

One of the most important aspects of the CDIO Syllabus is its internal organization. A syllabus, or template for learning outcomes, can be organized in many ways: the ABET accreditation criteria [4] are not subdivided into categories at all. The EQF characteristics [5] are categorized as Knowledge, Skills and Competences. The EUR-ACE accreditation criteria [6] are subdivided into Knowledge and Understanding, Engineering Analysis, Engineering Design, Investigations, Engineering Practice, and Transferable Skills.

The UNESCO Framework and the CDIO Syllabus

UNESCO [7] has proposed that all education should be organized around four fundamental types of learning:

- Learning to Know, that is, acquiring the instruments of understanding
- Learning to Do, so as to be able to act creatively on one's environment
- Learning to Live Together, so as to co-operate with other people
- Learning to Be, an essential progression that proceeds from the previous three

These four types of knowledge form a whole, because there are many points of contact, intersection and exchange among them. The UNESCO framework recognizes that a syllabus should elaborate the activities of a profession (Learning to do).

The organization of the CDIO Syllabus can be described as an adaptation of the UNESCO framework to the context of engineering education. At the first level, the CDIO Syllabus is divided into four categories:

1. *Technical Knowledge and Reasoning (or Learning to Know)*
   Section 1 of the CDIO Syllabus defines the mathematical, scientific and technical knowledge that an engineering graduate should have developed. This section is inherently specific to programs and disciplines. For example, the knowledge content of a chemical engineering education is different from that of a mechanical engineering education.
2. *Personal and Professional Skills and Attributes (or Learning to Be)*
   Section 2 of the Syllabus deals with individual skills, including problem solving, ability to think creatively, critically, and systemically, and professional ethics. In contrast to Section 1, Sections 2, 3, and 4 of the Syllabus define skills and abilities that are common to all engineering disciplines. All engineers solve problems, work with others, and contribute to the lifecycle of a product, process, or system.
3. *Interpersonal Skills: Teamwork and Communication (or Learning to Live Together)*
   Section 3 of the Syllabus lists skills that are needed in order to be able to work in groups and communicate effectively.

4. Conceiving, Designing, Implementing and Operating Systems in the Enterprise and Societal Context (or Learning to Do)
   Finally, Section 4 of the CDIO Syllabus is about what engineers do, that is, conceive-design-implement-operate products, processes and systems within an enterprise and societal context.

Although the UNESCO framework precedes the first draft of the CDIO Syllabus by several years, the original drafters of the Syllabus did not know of its existence. Thus, UNESCO and CDIO independently arrived at the same fundamental structure.

Levels of Detail

Another feature that distinguishes the CDIO Syllabus from other taxonomies of knowledge and skills is that it is far more detailed. The second level of the Syllabus, shown in Table 1, is comparable to the level of detail shown in most other documents. This is acceptable as a general guide to learning outcomes, but is far too little information to define detailed learning outcomes, design a curriculum or individual courses, or assess student learning. The two to three additional levels of details in the full CDIO Syllabus provide this information. (see Appendix A)

THE ROLE OF THE CDIO SYLLABUS IN EDUCATION

The CDIO Syllabus plays a central role in the design of an engineering education. As the formal statement of the intended learning outcomes of an engineering program, the Syllabus

- Captures the expressed needs of program stakeholders
- Highlights the overall goals of the program
- Provides a guide for the design of curriculum
- Suggests appropriate teaching and learning methods
- Provides the targets for student learning assessment, and
- Serves as a framework for overall program evaluation

In the curriculum and instructional design process, the CDIO Syllabus is adapted to a local engineering program in order to ensure that intended learning outcomes are aligned with institutional mission and vision, program objectives, and institutional and program values. (see Figure 1) This sometimes means that a program omits a few of the personal, interpersonal, and product, process, and system building skills found in the CDIO Syllabus, or add a few to highlight specific values of its institution.

The list of intended learning outcomes, adapted from the CDIO Syllabus, then serves as the basis for instructional decisions about curriculum, teaching and learning methods, and the assessment of student learning. In the curriculum design process at the program level, intended learning outcomes are detailed, sequenced from basic to complex, and mapped to appropriate levels and courses in the overall curriculum. For example, an intended learning outcome related to oral and written communication would be further defined into enabling steps and learning activities that would be integrated into courses at all levels of the curriculum so that by graduation, students would be able to demonstrate their competence in oral and written communication.

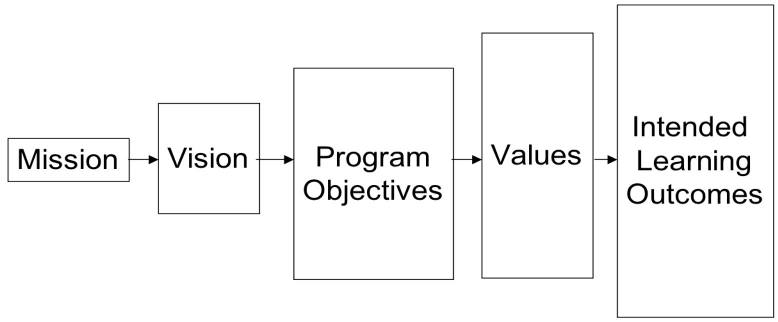

Figure 1. Alignment of intended learning outcomes with program mission

In the instructional design process at the course level, intended learning outcomes guide decisions about appropriate teaching, learning, and assessment methods. The appropriateness of teaching and assessment methods depends on the nature and level of the learning outcomes. Using the same example of communication, appropriate teaching and assessment methods would be those that would allow students to practice their skills, get feedback on their performance, and in an assessment situation, demonstrate their achievements. Biggs refers to this purposeful relationship between the intended learning outcomes, teaching and learning activities, and assessment of student learning as *constructive alignment*. [8] (see Figure 2) Wiggins and McTighe refer to the outcomes, teaching and learning, and assessment sequence as *backward design*. [9] With or without a specific name, all models of instructional design highlight the centrality of learning outcomes and the importance of the alignment of curriculum, teaching, and assessment. The CDIO Syllabus is a starting point for defining these learning outcomes.

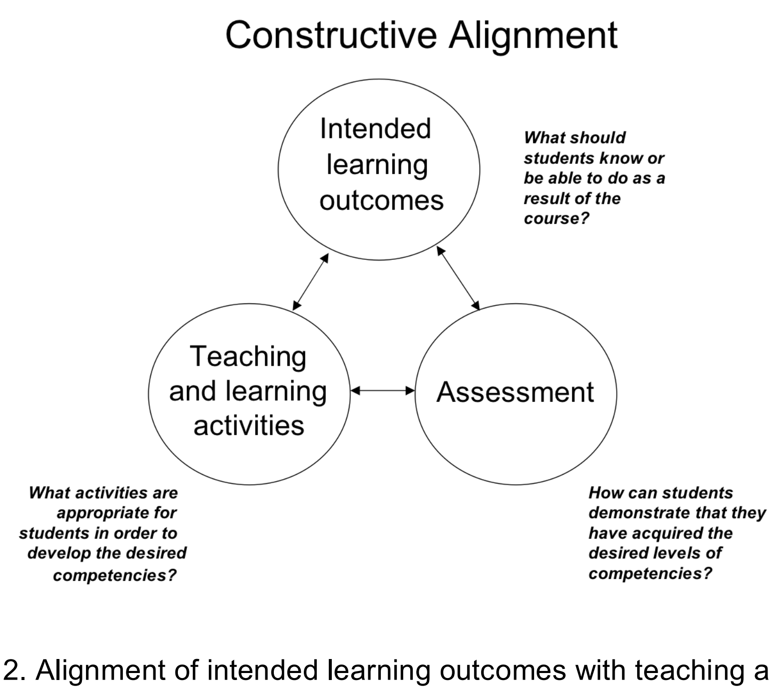

Figure 2. Alignment of intended learning outcomes with teaching and assessment

PROPOSED MODIFICATIONS TO THE CDIO SYLLABUS

Since the CDIO Syllabus was first drafted more than ten years ago, it has been a remarkably stable document, serving programs in all domains of engineering in educational institutions of all types throughout the world. However, there have been pressures to change the Syllabus. These pressures have two primary sources. The first pressure arises from the development of new taxonomies of knowledge that surface new issues or organizations that we should consider. The second pressure comes from questions from users of the Syllabus looking for clarification or for knowledge and skill areas that seem to be missing. In this section, we review the correlation of the CDIO Syllabus with other emerging documents, and then summarize the most frequently heard user concerns. The comparison with the UNESCO framework is discussed in the previous section.

Comparisons with National Accreditation and Evaluation Documents

The most common comparison documents for the CDIO Syllabus are those of national accreditation or evaluation bodies, usually produced by governments or professional societies. CDIO programs at different universities worldwide usually need to meet their respective national or accreditation standards, for example, ABET in the United States [4] or the National Agency for Higher Education in Sweden [10]. This need brings the correlation of the CDIO Syllabus with national outcomes requirements into focus. During the development of the first version of the CDIO Syllabus, it was correlated with the outcomes criteria of ABET EC2000. [3]. The most relevant section of ABET EC2000 is Criterion 3 on *Program Outcomes and Assessment*:

> Engineering programs must demonstrate that their graduates have
>
> (a) an ability to apply knowledge of mathematics, science, and engineering
> (b) an ability to design and conduct experiments, as well as to analyze and interpret data
> (c) an ability to design a system, component, or process to meet desired needs
> (d) an ability to function on multi-disciplinary teams
> (e) an ability to identify, formulate, and solve engineering problems
> (f) an understanding of professional and ethical responsibility
> (g) an ability to communicate effectively
> (h) the broad education necessary to understand the impact of engineering solutions in a global and societal context
> (i) a recognition of the need for, and an ability to engage in, life-long learning
> (j) a knowledge of contemporary issues
> (k) an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.

The correlation of the CDIO Syllabus with ABET EC2000 Criterion 3 is shown in Figure 3. One should note that this comparison generously interprets the ABET EC2000 criteria. The CDIO Syllabus reflects a more encompassing view of engineering than does ABET EC2000, by considering the full product/system/process lifecycle, including the implementing and operating life phases, whereas the ABET EC2000 criteria focus solely on the design phase. For example, Criterion 3(c) calls for "the ability to *design* a system, component or process to meet a desired need." However, since the word *process* was included in the definition, Figure 3 interprets the criterion to include the design of implementation and operation processes. In practice, a program could show satisfaction of Criterion 3(c) solely by demonstrating design of a part of the product. Overall, the CDIO Syllabus is well aligned with the ABET EC2000 criteria. The major advantage of the CDIO Syllabus is that it is more detailed, containing two or three more levels of detail than do the ABET EC2000 criteria. The increased levels of detail facilitate the interpretation of general statements, such as "communicate effectively", that are common in national outcomes requirements.

	ABET EC2000 Criterion 3										
CDIO Syllabus	a	b	c	d	e	f	g	h	i	j	k
1.1 Knowledge of Underlying Science	■										
1.2 Core Engineering Fundamentals	■										
1.3 Advanced Eng. Fundamental Knowledge	▒										■
2.1 Engineering Reasoning and Problem Solving					■						▒
2.2 Experimentation and Knowledge Discovery		■									
2.3 System Thinking			▒								
2.4 Personal Skills and Attitudes									■		
2.5 Professional Skills and Attitudes						■					▒
3.1 Multi-disciplinary Teamwork				■							
3.2 Communications							■				
3.3 Communication in a Foreign Language											
4.1 External and Societal Context								■		■	
4.2 Enterprise and Business Context											
4.3 Conceiving and Engineering Systems			■								
4.4 Designing			■								
4.5 Implementing			▒								
4.6 Operating			▒								
	■ Strong Correlation						▒ Good Correlation				

Figure 3. The CDIO Syllabus correlated with ABET EC2000 Criterion 3

In September 2008*, Engineers Canada,* through its Canadian Engineering Accreditation Board (CEAB), published a new set of accreditation criteria and procedures.[11] The criteria include 12 graduate attributes that are well correlated with the CDIO Syllabus:

3.1.1. Knowledge Base
3.1.2. Problem Analysis
3.1.3. Investigation
3.1.4. Design
3.1.5. Engineering Tools
3.1.6. Individual/Team Work
3.1.7. Communication
3.1.8. Professionalism
3.1.9. Society/Environment
3.1.10. Ethics and Equity
3.1.11. Economics and Project Management
3.1.12. Life-Long Learning

For example, *environmental issues* and *engineering tools* are a combination of *modeling* and *fundamental skills* in the CDIO Syllabus. The CDIO Syllabus at the third level of detail provides a more refined definition of the 12 graduate attributes specified in the new CEAB document, and can certainly help institutions to meet these new criteria. The correlation of the CDIO Syllabus with the CEAB criteria is illustrated in Figure 4.

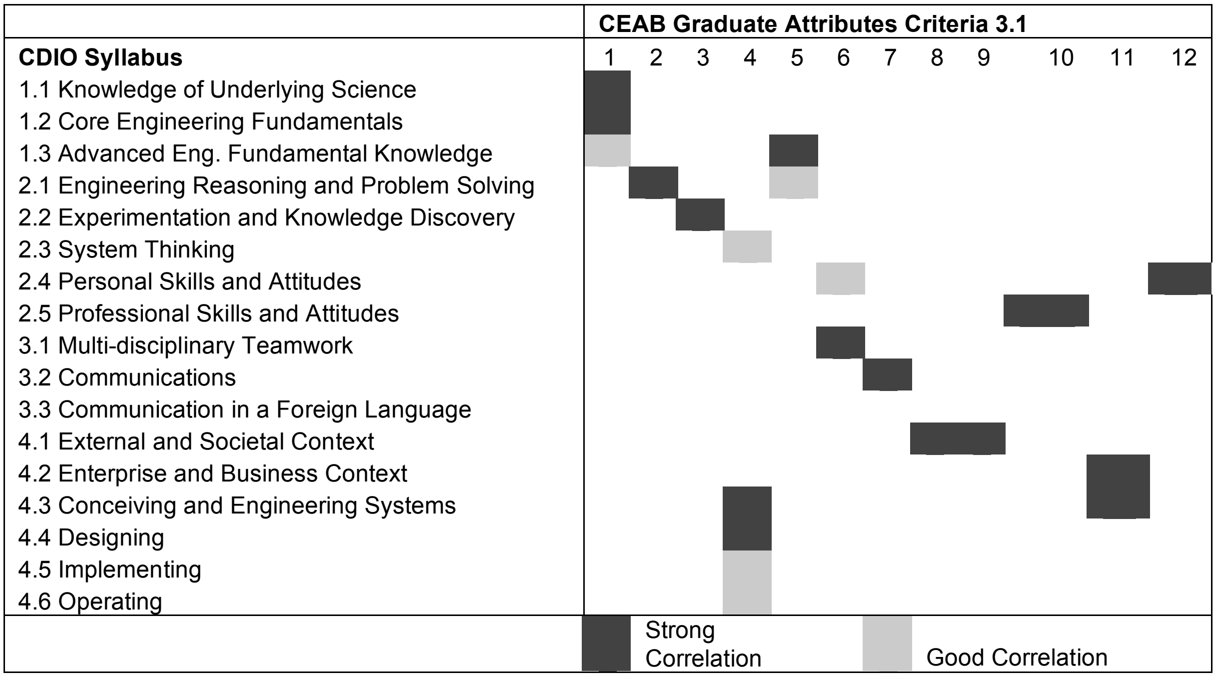

Figure 4. The CDIO Syllabus correlated with the CEAB Graduate Attributes

Subsequent analyses compared the CDIO Syllabus with national and international standards, such as the British UK-SPEC, the Dublin Descriptors, and the Swedish national engineering degree requirements [12], as well as the European EUR-ACE framework standards for accreditation of engineering programs [13]. Across all these comparisons, a similar pattern re-appears: The CDIO Syllabus states outcomes for engineering education that reflect a broader view of the engineering profession, and its greater levels of detail facilitate program and course development. A program whose design is based on the CDIO Syllabus will also fulfill its national requirements.

The principal modifications in the CDIO Syllabus that would be indicated by comparisons with national accreditation and evaluation documents might be clarifications of some of the topics so that the correspondence is more explicit. We proposed the following modifications to the CDIO Syllabus (see Appendix F):

- 1.0 -- Change to *Disciplinary or Subject-Based Knowledge and Reasoning* (Swedish Ordinance and EUR-ACE)
- 1.1 -- Add *Mathematics* (ABET)
- 1.3 -- Add *Methods and Tools* (ABET and CEAB)
- 2.1 -- Change to *Analytical Reasoning and Problem Solving* (ABET and CEAB)
- 2.2 -- Add *Investigation* to the title (CEAB)
- 2.5.1 -- Change to *Ethics, Integrity, and Social Responsibility* (ABET and CEAB)
- 2.5.2 -- Add *Professional Responsibility* (ABET)
- 2.5.5 – Add *Equity and Diversity* (CEAB)

- 3.1.5 -- Add *Multidisciplinary Teaming* (ABET and CEAB)
- 3.4.1 -- Add *Inquiry, Listening and Dialogue* (CEAB)
- 4.1 -- Add *Economic Context* (UK-SPEC)
- 4.2.5 -- Add part *Engineering Project Finance and Economics* (CEAB)
- 4.3.1 -- Add Understanding Needs (ABET and CEAB)
- 4.3.4 -- Add *Systems Engineering* (CEAB)
- 4.4.6 – Modify to indicate *safety* (CEAB)

Clarifications Based on User Feedback

Innovation and Invention

In the last decade, the concept of innovation as a role or purpose of engineering has become commonly accepted. However, there are several different understandings of the word *innovation*. The broader one is the development and exploitation of new ideas. A more specific understanding applicable to engineering is that innovation is *the development and introduction into the market of new goods and services*. If one accepts this latter definition, innovation is just the market-oriented view of what in the CDIO Syllabus defines in Sections 4.2 through 4.6 – Conceiving and Engineering Systems, Designing, Implementing, and Operating, within an enterprise. More emphasis may need to be placed on understanding the market and user needs as a basis for developing goals, but otherwise, the skills and knowledge necessary to foster innovation is completely covered in the CDIO Syllabus.

Invention refers to the development of new technologies that may enable innovations, including their incorporation into products and services that will be delivered. While invention is present in the CDIO Syllabus, it is made explicit only at the fourth level of detail, under 4.2.2 and 4.2.3. It may be better to raise the visibility of this important engineering function.

With respect to innovation and invention, the following modifications to the CDIO Syllabus are proposed (see Appendix F):

- 4.0 -- Add *Innovation* to the title
- 4.2.2 -- Change to *Enterprise Stakeholders, Strategy and Goals*
- 4.2.5 -- Add *Engineering Project Finance and Economics*
- 4.2.6 -- Add *New Technology Development, Assessment and Infusion*
- 4.3.1 -- Change to Understanding Needs and Setting Goals

Sustainability

During the last decade, the importance of sustainable development has become widely recognized. Future engineers need to be able to mitigate the negative environmental consequences of current energy and production systems, and create new ones that are essentially carbon neutral. It follows that engineering education must emphasize sustainability principles. In this context, the CDIO Syllabus, v.1, has received some criticism, as sustainability is mentioned in only one place, at the fourth level of detail, under 4.4.6. The low visibility has been interpreted as insufficient emphasis on this topic.

However, it can also be argued that CDIO is fundamentally aligned with the ideas of sustainability: Engineers are said to conceive, design, implement and operate complex technical systems with the entire product/process/system lifecycle in mind. Moreover, sustainability is a complex concept. It includes the three main dimensions: economic, environmental, and social sustainability, including both subject matter and judgmental aspects, such as, ethics and decision-making [14]. There are many places in the CDIO Syllabus that emphasize the lifecycle perspective, for example, requirements should cover all phases of the lifecycle; analyses should be made of lifecycle values and costs; and product retirement should be planned ahead. With this broader perspective in mind, links between sustainability principles and CDIO Syllabus topics can be identified [15]. In essence, we conclude that the CDIO Syllabus does support the development of an engineering education that strongly considers sustainability. Nevertheless, the visibility of the concept of sustainability could be strengthened in the CDIO Syllabus, signaling its importance to students, industry, and program and course developers.

Based on these issues of *sustainability*, the following modifications to the CDIO Syllabus are proposed (see Appendix F):

- 4.0 -- Include *Environmental* in the title
- 4.1 -- Include *Environmental* in the title
- 4.1.7 -- Add Sustainability and the Need for Sustainable Development
- 4.4.6 -- Make *Design for Sustainability* more explicit
- 4.5.1 -- Change to *Designing a Sustainable Implementation Process*
- 4.6.1 -- Change to *Designing and Optimizing Sustainable and Safe Operations*

Other Critiques and Inputs

Over the years, several universities have observed that the CDIO Syllabus does not place sufficient emphasis on the topics of ethics, morality, and social responsibility. For example, The Pontifical Catholic University of Chile adapted the CDIO Syllabus to their program by adding to 2.4 the following (translated from the Spanish): *Commitment to Christian principles; Concern for those in great need*; and *Concern for the environment.*

Others have observed that, while the CDIO Syllabus covers aspects of formal communication well, that is, writing, oral presentations, and graphics, it could do better with informal and interpersonal communications. This would include topics such as social networking, negotiation, active listening, and persuading.

Another important critique is based on the work of Johan DeGraeve, which proposes a *Five-E Model* for engineering education. The model, developed at Group T International University College in Leuven, Belgium, describes five "*E*" terms around which their program of educating *integral engineers* is built. The first three *E*'s represent the roles engineers play in society.

- *ENGINEERING* -- making things
  Integral engineers create by making use of technology and the underlying sciences. They are familiar with a multidisciplinary approach.
- *ENTERPRISING* -- getting things done
  Integral engineers have vision. On this basis, they define a mission around which they gather others. Through innovation, daring and leadership they effectively get things done.
- *EDUCATING* -- developing oneself and others
  Integral engineers are capable of coaching themselves, others, and teams. Their ideal is the development of each and everyone.
- *ENVIRONMENTING* -- embracing all elements
  Integral engineers are conscious of the influence of technology on the world, and

vice versa. This is why they take into account the impact of their actions on ethics, ecology, aesthetics and economics within a globalizing and ever-evolving world.

- *ENSEMBLING* -- transcending and including
  Integral engineers see the coherence of things. By differentiating and integrating, and approaching all things from different angles, they achieve deeper insights and arrive at ever-richer experiences. [16]

These five *E*'s are not really an addition to the CDIO Syllabus, but rather an overlay or a view through a different lens.

Based on these critiques and inputs, we propose the following modificaitonsto the CDIO Syllabus (see Appendix F):

- 2.4.6 -- Add *Educating Others*
- 2.4.8 -- Add *Knowledge Integration (Ensembling)*
- 2.5.1 -- Change to *Ethics, Integrity, and Social Responsibility*
- 3.4 -- Add new listing *Informal Communication* to include:
    - 3.4.1 *Inquiry, Listening, and Dialogue*
    - 3.4.2 *Negotiation, Compromise and Conflict Resolution*
    - 3.4.3 *Advocacy*
    - 3.4.4 *Establishing diverse Connections (Grouping)*

LEADERSHIP AND ENTREPRENEURSHIP: CDIO+LE

In modern society, engineers are increasingly expected to move to positions of leadership and to take on additional roles as entrepreneurs. Leadership is not necessarily positional, that is, a leader need not be a boss, manager, director or president. *Leadership* refers to the role of helping to organize effort, create vision, and facilitate the work of others. In the context of engineering, senior engineers are the ones who most often lead. *Entrepreneurship* refers to the specific activity of creating and leading a new enterprise. Many, but not all, new enterprises are built around a product or technology, and involve entrepreneurial engineers. In this section, we explore the degree to which *leadership* and *entrepreneurship* are already included in the CDIO Syllabus, and the extensions that might be necessary to more adequately address these two important roles of engineers.

Engineering leadership and entrepreneurship are not orthogonal to the skills already contained in the CDIO Syllabus. After all, the goal of the CDIO approach, as described above, is "To educate students who are able to:

- Master a deeper working knowledge of technical fundamentals
- <u>Lead</u> in the creation and operation of new products, processes, and systems…"

The knowledge, skills, and attitudes needed in the creation and operation of new products, processes, and systems should, therefore, already be contained in the CDIO Syllabus. In fact, there is a broad overlap, both between leadership and entrepreneurship, and between the two of them and the skills already in the Syllabus. To a certain extent, the three are just different profiles of the same broader set of skills, as suggested in Figure 5. This Venn diagram suggests the organization of the discussion that follows. We have already reviewed the CDIO Syllabus, v. 1, with its proposed modifications. Here, we discuss what could be added to expand the topics in the Syllabus beyond the already proposed modifications, to include *Engineering*

Leadership. Finally, we examine what other topics are needed to embrace *Entrepreneurship.* We recognize that many programs are using the CDIO Syllabus, v.1 (or will use the proposed v. 2.0), and may not want to address leadership and entrepreneurship in their programs. For this reason, we propose a new, second-level document, the *CDIO+LE Syllabus*, with the additional content discussed below.

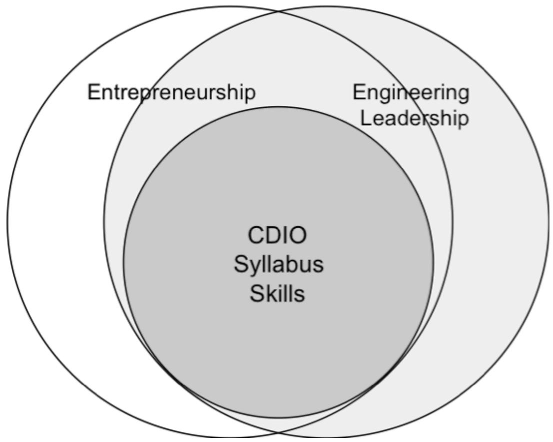

Figure 5. The overlapping relationship between the knowledge, skills and attitudes in the CDIO Syllabus v.1, engineering leadership, and entrepreneurship

The Expansion of the CDIO Syllabus to Include Engineering Leadership: CDIO+L

Some, if not all, engineers will move, at some point in their careers, to positions of technical or engineering leadership, ranging from being a leader of a small team, to being the technical leader of an entire enterprise. Leadership is explicitly discussed in Section 3.1.4 of the CDIO Syllabus, but this is really about leading small groups, and is only a placeholder for the wider set of skills that an engineering leader is required to have. These skills include character traits, such as loyalty and integrity, and abilities, such as the ability to make sense of complex contextual information, to relate and persuade, to create transformational visions, and to deliver on those visions. In this section, we discuss relevant contemporary models of leadership, and propose extensions to the CDIO Syllabus.

Leadership Models

Much has been written over the years about the qualities of a leader. In contemporary scholarship, organizational leadership is closely studied by those in organizational behavior groups, often at schools of business or management. Diverse fields, including business, government, and the military have adopted these organizational models, and customized them to their respective domains. Generic models of leadership, then, can be customized for engineering contexts.

Among the many views of leadership development, the general approaches that may best fit engineering contexts are those that function in environments of change, uncertainty, and the deliberate pursuit of invention. [17] One school of thought that stands out is *Transformational Leadership* because of its emphasis on a driving need to change and to mobilize resources in new ways, requiring new visions of the future. [18]

This model resonates with leaders of groups that are using applied science and engineering to generate new products that may require redefining markets and business models.

Contingency theory reminds leaders that over time no single approach to leadership will fit all situations, and one must continually assess one's environment to provide appropriate leadership. [19] This approach thus incorporates the importance of providing vision and strong direction in one circumstance, and also recognizes when one might lead best by creating a stable and supportive environment in which others might lead. This view suggests that engineering leadership in a change-driven environment is situational. [20] The complex and specialized nature of engineering requires that leadership be found everywhere. There are instances when one must be able to listen to the technician on the shop floor who might be the first to see the solution to a design-for-production problem. In advancing technical fields, the individuals looking outward from the company at new technologies, and those working in an organization's laboratories, provide a kind of technology leadership. Other who follow markets, and observe novel uses of products that are enhancing or eroding markets, must exert a kind of situational leadership as well. All of these leaders need first to recognize that change is occurring, to make sense of what they are seeing and to communicate effectively with others.

The Four Capabilities Leadership Framework

The *Four Capabilities Leadership Framework,* developed at the Sloan School of Management at MIT, provides a scheme that organizes key leadership concepts as a foundation for engineering leadership education. [21] It begins with four assumptions: that leadership is distributed; that it is personal; that it continues to develop throughout one's career, and thus changes over time; and that each individual invents their own framework for how he/she will lead. The central skills are

1. *Sensemaking* -- making sense of the context of the changing world around us, including the use of small experiments to test and gain information
2. *Relating* -- developing trusted relationships with diverse individuals, using inquiry to know how to communicate effectively. and leadership through advocacy, even if one is not a formal leader
3. *Visioning* -- both to create a vision for oneself and to convey that vision to others
4. *Realizing the Vision* (*Inventing*) -- takes on a more complex meaning for engineers. Engineering leaders, like other leaders, need to invent ways to think through situations, and create ways of organizing their work with others. For engineers, the tasks of organizing work are central to their profession. This organization may involve establishing design teams, designing, setting up production and implementation, establishing who will do testing and by what means, operating, and a host of other activities.

In the Bernard M. Gordon – MIT Engineering Leadership Program, we have been working on adapting this more generic model of leadership to the context of engineering. We have added to the MIT Sloan Four Capabilities Model a leading set and a final set of skills and attributes. The first set includes issues of leadership that have to do with attitudes and character, for example, initiative, the will to deliver, resourcefulness, integrity, and loyalty. The last set concentrates on a firm foundation of engineering knowledge and skills. The customized leadership model has six central skills:

1. The Attitudes of Leadership (Core Personal Values and Character)
2. Relating to Others

3. Making Sense of the Context
4. Creating a Purposeful Vision
5. Realizing the Vision
6. Technical Knowledge and Critical Reasoning

The full description of the *Gordon-MIT Engineering Leadership Program Capabilities of an Engineering Leader* can be found at http://web.mit.edu/gordonelp/Capabilities.html.

When one compares the structure of the *Gordon-MIT Engineering Leadership Program Capabilities of an Engineering Leader* with the existing CDIO Syllabus, including the proposed modifications, we see a great deal of overlap. The newly proposed section 4.7 of the CDIO+LE Syllabus summarizes the overlap and identifies aspects of new content that should be added. In order to better prepare engineering students for leadership, we propose the following modifications to Version 2.0 of the CDIO Syllabus (see Appendix F):

- 2.5 -- Add the reorganized and expanded list of attitudes and personal skills indicated in the new 2.5.6 to 2.5.11
- 3.1.4 -- Re-label *Team Leadership*
- 3.4 -- Add a new section on Informal Communication, including the previously defined 3.4.1 to 3.4.4

In addition, we recommend adding the entire section 4.7 *Leading Engineering Endeavors*, but only to the CDIO+LE Syllabus. This new section defines the remaining topics in *Creating a Purposeful Vision* (4.7.1 to 4.7.3) and *Realizing the Vision* (4.7.4 to 4.7.9) (see Appendix F):

- 4.7.1 -- *Thinking Creatively and Imagining Possibilities* (expands *Creative Thinking* 2.4.3)
- 4.7.2 -- *Defining the Solution* (expands *Understanding Needs and Setting Goals* 4.3.1)
- 4.7.3 -- *Creating New Solution Concepts* (expands 4.3.2 and 4.3.3)
- 4.7.4 -- *Building and Leading an Organization and an Extended Organization* (builds on 4.2.4)
- 4.7.5 -- *Planning and Managing a Project to Completion* (builds on 4.3.4)
- 4.7.6 -- *Exercising Project/Solution Judgment*
- 4.7.7 -- *Innovation* – the conception, design and introduction of new goods and services (builds on 4.4)
- 4.7.8 -- *Invention* – the development of new devices, materials or processes that enable new goods and services
- *4*.7.9 -- *Implementation and Operation* – the creation and operation of the goods and services that will deliver value (the leadership of 4.5 and 4.6)

The Expansion of the CDIO Syllabus to Include Entrepreneurship: CDIO+L+E

Successful engineering entrepreneurship consists of engineering, plus engineering leadership, plus specific domain knowledge associated with business formulation and start-ups. As illustrated in Figure 5, we now define the knowledge and skills necessary for *Entrepreneurship*, over and above those described in the baseline CDIO Syllabus, v. 2.0, with the proposed additions for engineering *Leadership*. Again, we examine appropriate models of entrepreneurship on which to base our discussion.

In the view of classical economics, *entrepreneurship* involves the redirection and mobilization of capital and human resources to form a new economic activity. This perspective considers any major innovation in an established firm to be entrepreneurship if it involves a novel economic activity that departs from the firm's prior business model, and accepts the risks of placing substantial investments in new products and creating new markets that did not previously exist. Today, the term *entrepreneurship* generally refers exclusively to starting a new company, while launching a radically new line of business is sometimes called *intrapreneurship,* or more simply *innovation* (as was discussed in a previous section). [22]

Engineering education should prepare students for both forms of entrepreneurship, which are more easily accommodated than intrapreneurship. In many instances, science- and technology-based discovery and invention in established companies may not require business innovation because often they do not require changes in markets. When engineering is a major component of a product that is intended to disrupt existing markets, much more care is needed in the design process, and the engineer needs to understand the trade-offs between product novelty and importance of time to market, product margins and hurdle rates needed to justify company investment, and other business considerations that influence design and implementation strategies. These issues are well addressed in the product development literature and can be included without difficulty in any engineer's education. In the context of the CDIO Syllabus, these aspects of learning would be largely addressed by the modifications discussed with respect to innovation.

Preparation for entrepreneurship, that is, the start of a new company, involves unique competencies. There are analogues, such as the similarity between recognizing new opportunities enabled by advancing technology, or writing business plans for either a new product line or a new company. However, there is an array of skills that engineers in an established company might never face, such as finding and hiring an entire company of talented professionals willing to accept risk, using equity to motivate innovation, or creating a new company culture where none existed.

In order to capture these additional skills of entrepreneurship, we propose that Section 4.8 be added to the CDIO+LE Syllabus. This new section would include the following topics (see Appendix F):

- 4.8.1 -- *Company Founding, Formulation, and Organization*
- 4.8.2 – *Business Plan Development*
- 4.8.3 -- *Company Capitalization and Finances*
- 4.8.4 -- *Innovative Product Marketing*
- 4.8.5 -- *Conceiving Products and Services Around New Technologies*
- 4.8.6 – *The Innovation System, Networks, Infrastructure, and Services*
- 4.8.7 -- *Building the Team and Initiating Engineering Processes* (conceiving, designing, implementing and operating)
- 4.8.8 -- *Managing Intellectual Property*

SUMMARY

This paper has presented the following key concepts:

- The CDIO Syllabus is a rational, detailed, and relatively complete taxonomy for the knowledge, skills, and attitudes that graduating engineers should possess; and, it has been stable for almost ten years

- Its high-level structure is consistent with the four pillars of learning outlined by UNESCO
- It can be instrumental in the design of constructively aligned learning outcomes, curricula, teaching approaches, student learning assessment, and program evaluation
- The CDIO Syllabus is well aligned with other outcomes-based taxonomies developed by national accreditation and evaluation bodies, and has been found to be more comprehensive and more detailed
- Based on comparisons with other taxonomies, and the frequent user questions raised over the years, particularly around innovation, invention, and sustainability, modifications in content and in labeling are proposed to the baseline CDIO Syllabus, creating Version 2.0
- In order to better serve programs interested explicitly in engineering leadership and entrepreneurship, an expanded document is proposed, called the *CDIO+LE Syllabus*

In summary, we have found the CDIO Syllabus to be a remarkably robust document, but one that can be improved. We propose two steps: the incorporation of modest changes to the baseline CDIO Syllabus, and the creation of an extended version covering leadership and entrepreneurship.

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APPENDIX A. The CDIO Syllabus (English)

1 TECHNICAL KNOWLEDGE AND REASONING
- 1.1. KNOWLEDGE OF UNDERLYING SCIENCES
- 1.2. CORE ENGINEERING FUNDAMENTAL KNOWLEDGE
- 1.3. ADVANCED ENGINEERING FUNDAMENTAL KNOWLEDGE

2 PERSONAL AND PROFESSIONAL SKILLS AND ATTRIBUTES
- 2.1. ENGINEERING REASONING AND PROBLEM SOLVING
  - 2.1.1. Problem Identification and Formulation
  - 2.1.2. Modeling
  - 2.1.3. Estimation and Qualitative Analysis
  - 2.1.4. Analysis With Uncertainty
  - 2.1.5. Solution and Recommendation
- 2.2. EXPERIMENTATION AND KNOWLEDGE DISCOVERY
  - 2.2.1. Hypothesis Formulation
  - 2.2.2. Survey of Print and Electronic Literature
  - 2.2.3. Experimental Inquiry
  - 2.2.4. Hypothesis Test, and Defense
- 2.3. SYSTEM THINKING
  - 2.3.1. Thinking Holistically
  - 2.3.2. Emergence and Interactions in Systems
  - 2.3.3. Prioritization and Focus
  - 2.3.4. Tradeoffs, Judgment and Balance in Resolution
- 2.4. PERSONAL SKILLS AND ATTITUDES
  - 2.4.1. Initiative and Willingness to Take Risks
  - 2.4.2. Perseverance and Flexibility
  - 2.4.3. Creative Thinking
  - 2.4.4. Critical Thinking
  - 2.4.5. Awareness of One's Personal Knowledge, Skills, and Attitudes
  - 2.4.6. Curiosity and Lifelong Learning
  - 2.4.7. Time and Resource Management
- 2.5. PROFESSIONAL SKILLS AND ATTITUDES
  - 2.5.1. Professional Ethics, Integrity, Responsibility and Accountability
  - 2.5.2. Professional Behavior
  - 2.5.3. Proactively Planning for One's Career
  - 2.5.4. Staying Current on World of Engineer

3 INTERPERSONAL SKILLS: TEAMWORK AND COMMUNICATION
- 3.1. TEAMWORK
  - 3.1.1. Forming Effective Teams
  - 3.1.2. Team Operation
  - 3.1.3. Team Growth and Evolution
  - 3.1.4. Leadership
  - 3.1.5. Technical Teaming
- 3.2. COMMUNICATION
  - 3.2.1. Communication Strategy
  - 3.2.2. Communication Structure
  - 3.2.3. Written Communication
  - 3.2.4. Electronic/Multimedia Communication
  - 3.2.5. Graphical Communication
  - 3.2.6. Oral Presentation and Interpersonal Communication
- 3.3. COMMUNICATION IN FOREIGN LANGUAGES
  - 3.3.1. English
  - 3.3.2. Languages within the European Union
  - 3.3.3. Languages outside the European Union

4 CONCEIVING, DESIGNING, IMPLEMENTING AND OPERATING SYSTEMS IN THE ENTERPRISE AND SOCIETAL CONTEXT
- 4.1. EXTERNAL AND SOCIETAL CONTEXT
  - 4.1.1. Roles and Responsibility of Engineers
  - 4.1.2. The Impact of Engineering on Society
  - 4.1.3. Society's Regulation of Engineering
  - 4.1.4. The Historical and Cultural Context
  - 4.1.5. Contemporary Issues and Values
  - 4.1.6. Developing a Global Perspective
- 4.2. ENTERPRISE AND BUSINESS CONTEXT
  - 4.2.1. Appreciating Different Enterprise Cultures
  - 4.2.2. Enterprise Strategy, Goals and Planning
  - 4.2.3. Technical Entrepreneurship
  - 4.2.4. Working Successfully in Organizations
- 4.3. CONCEIVING AND ENGINEERING SYSTEMS
  - 4.3.1. Setting System Goals and Requirements
  - 4.3.2. Defining Function, Concept and Architecture
  - 4.3.3. Modeling of System and Ensuring Goals Can Be Met
  - 4.3.4. Development Project Management
- 4.4. DESIGNING
  - 4.4.1. The Design Process
  - 4.4.2. The Design Process Phasing and Approaches
  - 4.4.3. Utilization of Knowledge in Design
  - 4.4.4. Disciplinary Design
  - 4.4.5. Multidisciplinary Design
  - 4.4.6. Multi-objective Design
- 4.5. IMPLEMENTING
  - 4.5.1. Designing the Implementation Process
  - 4.5.2. Hardware Manufacturing Process
  - 4.5.3. Software Implementing Process
  - 4.5.4. Hardware Software Integration
  - 4.5.5. Test, Verification, Validation and Certification
  - 4.5.6. Implementation Management
- 4.6. OPERATING
  - 4.6.1. Designing and Optimizing Operations
  - 4.6.2. Training and Operations
  - 4.6.3. Supporting the System Lifecycle
  - 4.6.4. System Improvement and Evolution
  - 4.6.5. Disposal and Life-End Issues
  - 4.6.6. Operations Management

APPENDIX B. The CDIO Syllabus (Swedish)

CDIO – Måldokument

MATEMATISKA, NATURVETENSKAPLIGA OCH TEKNIKVETENSKAPLIGA KUNSKAPER

- **KUNSKAP I GRUNDLÄGGANDE MATEMATISKA OCH NATURVETENSKAPLIGA ÄMNEN**
- **KUNSKAP I TEKNIKVETENSKAPLIGA ÄMNEN**
- **FÖRDJUPADE KUNSKAPER I NÅGOT/NÅGRA TILLÄMPADE ÄMNEN**

INDIVIDUELLA OCH YRKESMÄSSIGA FÄRDIGHETER OCH FÖRHÅLLNINGSSÄTT

- **INGENJÖRSMÄSSIGT TÄNKANDE OCH PROBLEMLÖSANDE**
  - **Problemidentifiering och formulering**
  - **Modellering**
  - **Kvantitativa och kvalitativa uppskattningar**
  - **Analys med hänsyn till osäkerheter och risker**
  - **Slutsatser och rekommendationer**
- **EXPERIMENTERANDE OCH KUNSKAPSBILDNING**
  - **Hypotesformulering**
  - **Informationskompetens**
  - **Experimentell metodik**
  - **Hypotesprövning**
- **SYSTEMTÄNKANDE**
  - **Helhetstänkande**
  - **Interaktion och framträdande egenskaper hos system**
  - **Prioritering och fokusering**
  - **Kompromisser och avvägningar i val av lösningar**
- **INDIVIDUELLA FÄRDIGHETER OCH FÖRHÅLLNINGSSÄTT**
  - **Initiativförmåga och risktagande**
  - **Uthållighet och anpassningsförmåga**
  - **Kreativt tänkande**
  - **Kritiskt tänkande**
  - **Självkännedom**
  - **Nyfikenhet och livslångt lärande**
  - **Planering av tid och resurser**
- **PROFESSIONELLA FÄRDIGHETER OCH FÖRHÅLLNINGSSÄTT**
  - **Yrkesetik, integritet, ansvar och pålitlighet**
  - **Professionellt uppträdande**
  - **Aktiv karriärplanering**
  - **Att hålla sig à jour med professionens utveckling**

FÖRMÅGA ATT ARBETA I GRUPP OCH ATT KOMMUNICERA

- **ATT ARBETA I GRUPP**
  - **Att skapa effektiva grupper**
  - **Grupparbete**
  - **Grupputveckling**
  - **Ledarskap**
  - **Gruppsammansättning**

- **ATT KOMMUNICERA**
  - **Kommunikationsstrategi**
  - **Budskapets struktur**
  - **Skriftlig framställning**
  - **Multimedia och elektronisk kommunikation**
  - **Grafisk kommunikation**
  - **Muntlig framställning**

- **ATT KOMMUNICERA PÅ FRÄMMANDE SPRÅK**
  - **Engelska**
  - **Språk i länder av regionalt industriellt intresse**
  - **Andra språk**

PLANERING, UTVECKLING, REALISERING OCH DRIFT AV TEKNISKA SYSTEM MED HÄNSYN TILL AFFÄRSMÄSSIGA OCH SAMHÄLLELIGA BEHOV OCH KRAV

- **SAMHÄLLELIGA VILLKOR**
  - **Ingenjörens roll och ansvar**
  - **Teknikens roll i samhället**
  - **Samhällets regelverk**
  - **Historiska perspektiv och kulturella sammanhang**
  - **Aktuella frågor och värderingar**
  - **Utvecklande av ett globalt perspektiv**

- **FÖRETAGS- OCH AFFÄRSMÄSSIGA VILLKOR**
  - **Förståelse för olika affärskulturer**
  - **Planering, strategier och mål för affärsverksamhet**
  - **Teknikbaserat entreprenörskap**
  - **Att arbeta framgångsrikt i en organisation**

- **ATT PLANERA SYSTEM**
  - **Att specificera systemmål och -krav**
  - **Att definiera systemets funktion, koncept och arkitektur**
  - **Att modellera system och att säkerställa måluppfyllelse**
  - **Ledning av utvecklingsprojekt**

- **ATT UTVECKLA SYSTEM**
  - **Konstruktionsprocessen**
  - **Konstruktionsprocessens faser och metodik**
  - **Kunskapsanvändning vid konstruktion**
  - **Disciplinär konstruktion (inom ett teknikområde, t.ex. hydraulikkonstruktion)**
  - **Multidisciplinär konstruktion**
  - **Konstruktion med hänsyn till multipla, motstridiga mål**

- **ATT REALISERA SYSTEM**
  - **Utformning av realiseringsprocessen**
  - **Tillverkning av hårdvara**
  - **Implementering av mjukvara**
  - **Integration av mjuk- och hårdvara**
  - **Test, verifiering, validering och certifiering**
  - **Ledning av realiseringsprocessen**

- **ATT TA I DRIFT OCH ANVÄNDA**
  - **Att utforma och optimera driften**
  - **Utbildning för drift**
  - **Systemunderhåll**
  - **Systemförbättring och -utveckling**
  - **Systemavveckling**
  - **Driftsledning**

APPENDIX C. The CDIO Syllabus (French)

Translated Into French by École Polytechnique de Montréal

1 CONNAISSANCES TECHNIQUES ET RAISONNEMENT
- **1.1 CONNAISSANCE DES SCIENCES DE BASE [a]**
- **1.2 CONNAISSANCE DES PRINCIPES FONDAMENTAUX D'INGÉNIERIE [a]**
- **1.3 CONNAISSANCES AVANCÉES EN INGÉNIERIE [k]**

2 COMPÉTENCES ET HABILETÉS PROFESSIONNELLES ET PERSONNELLES
- **2.1 RAISONNEMENT TECHNIQUE ET RÉSOLUTION DE PROBLÈMES [e]**
  - 2.1.1 Identification de problèmes et formulation
  - 2.1.2 Modélisation
  - 2.1.3 Estimation et analyse qualitative
  - 2.1.4 Analyse d'incertitude
  - 2.1.5 Solutions et recommandations
- **2.2 EXPÉRIMENTATION ET DÉCOUVERTE SCIENTIFIQUE [b]**
  - 2.2.1 Formulation d'hypothèses
  - 2.2.2 Documentation écrite et électronique
  - 2.2.3 Enquête expérimentale
  - 2.2.4 Vérification d'hypothèses et tactique d'étude
- **2.3 PENSÉE SYSTÉMIQUE**
  - 2.3.1 Pensée holistique
  - 2.3.2 Émergence et interaction de systèmes
  - 2.3.3 Établissement des priorités et focalisation
  - 2.3.4 Compromis technique, discernement et vue d'ensemble dans la résolution de problèmes
- **2.4 HABILETÉS ET ATTRIBUTS PERSONNELS**
  - 2.4.1 Avoir de l'initiative et savoir prendre des risques
  - 2.4.2 Persévérence et flexibilité
  - 2.4.3 Pensée créative
  - 2.4.4 Pensée critique
  - 2.4.5 Être sensible aux connaissances, habiletés et attitudes des autres
  - 2.4.6 Curiosité intellectuelle et intérêt pour l'acquisition continue du savoir [i]
  - 2.4.7 Gestion du temps et des ressources
- **2.5 HABILETÉS ET COMPÉTENCES PROFESSIONNELLES**
  - 2.5.1 Éthique professionnelle, intégrité, responsabilité et fiabilité [f]
  - 2.5.2 Conduite empreinte de professionnalisme
  - 2.5.3 Planification de carrière proactive
  - 2.5.4 Mise à jour des connaissances en ingénierie

3 HABILETÉS INTERPERSONNELLES, TRAVAIL D'ÉQUIPE ET COMMUNICATION
- **3.1 TRAVAIL D'ÉQUIPE [d]**
  - 3.1.1 Savoir former des équipes efficaces
  - 3.1.2 Organisation en équipe
  - 3.1.3 Croissance et évolution des groupes
  - 3.1.4 Savoir diriger
  - 3.1.5 Organisation d'équipes techniques
- **3.2 COMMUNICATIONS [g]**
  - 3.2.1 Stratégies de communication
  - 3.2.2 Structure des communications
  - 3.2.3 Communication écrite
  - 3.2.4 Communication électronique et multimédia
  - 3.2.5 Communication de données graphiques
  - 3.2.6 Techniques de présentations orales et communication interpersonnelle
- **3.3 COMMUNICATION EN LANGUE ÉTRANGÈRE**
  - 3.3.1 Anglais
  - 3.3.2 Langues régionales des nations industrialisées
  - 3.3.3 Autres langues

4 IMAGINER, CONCEVOIR, RÉALISER ET EXPLOITER DES SYSTÈMES DANS UN CONTEXTE SOCIÉTAL ET D'ENTREPRISE

4.1 CONTEXTE EXTERNE ET SOCIÉTAL [h]

4.1.1 Les rôles et responsabilités d'un ingénieur
4.1.2 L'impact de l'ingénierie dans la société
4.1.3 Règlementation de l'ingénierie
4.1.4 Le contexte historique et culturel
4.1.5 Les valeurs et les enjeux contemporains [j]
4.1.6 Développement d'une perspective globale

4.2 CONTEXTE COMMERCIAL ET D'ENTREPRISE

4.2.1 Compréhension des différentes cultures corporatives
4.2.2 Stratégie d'entreprise, établissement des objectifs et planification
4.2.3 Entrepreneuriat technique
4.2.4 Savoir travailler efficacement au sein d'une organisation

4.3 IMAGINER ET CONCEPTUALISER DES SYSTÈMES D'INGÉNIERIE [c]

4.3.1 Établir les objectifs et les spécifications d'un système
4.3.2 Définir les fonctions, le concept et l'architecture
4.3.3 Modélisation de systèmes et atteinte des objectifs
4.3.4 Développement et gestion de projets

4.4 CONCEVOIR [c]

4.4.1 Processus de conception
4.4.2 Mise en phase du processus de conception et de l'information afférente
4.4.3 Organisation de l'information dans le cadre de la conception
4.4.4 Conception à l'intérieur d'une discipline
4.4.5 Conception dans un cadre multidisciplinaire
4.4.6 Conception à objectifs multiples(DFX)

4.5 RÉALISER [c]

4.5.1 Conception du processus de mise en œuvre
4.5.2 Processus de fabrication du matériel
4.5.3 Processus de réalisation d'un logiciel
4.5.4 Intégration matériel-logiciel
4.5.5 Test, vérification, validation, et certification
4.5.6 Gestion de la mise en œuvre

4.6 EXPLOITER [c]

4.6.1 Conception et optimisation des opérations
4.6.2 Formation et opérations
4.6.3 Cycle de vie d'un système
4.6.4 Amélioration et évolution des systèmes
4.6.5 Questions relatives à la fin d'un systèmes
4.6.6 Gestion des opérations

APPENDIX D. The CDIO Syllabus (Spanish)
(Traducción FCFM - Universidad de Chile)

1,1 Demostrar capacidad de usar los principios de las ciencias básicas
1,2 Aplicar los principios de las ciencias de la ingeniería
1,3 Demostrar capacidad de aplicar el conocimiento de las áreas profesionales de la ingeniería.

<u>2. Habilidades y atributos personales y profesionales</u>

2,1 Analizar y Resolver problemas de Ingeniería

- Identificar y formular problemas
- Crear y usar modelos
- Estimar y analizar problemas en forma cualitativa
- Analizar problemas bajo condiciones de incertidumbre
- Resolver problemas y hacer recomendaciones

2,2 Conducir investigación y experimentos sobre problemas ingenieriles

- Formular hipotesis
- Realizar búsquedas de la literatura escrita y electrónica
- Conducir investigaciones experimentales
- Probar y defender hipotesis

2,3 Pensamiento sistémico

- Pensar holísticamente
- Reconocer la aparición de nuevas propiedades y la interacción entre elementos de un sistema.
- Identificar factores, sus prioridades y detectar aquellos de mayor relevancia
- Identificar trade offs (tasa de sustitución) y, elección de soluciones que balancean múltiples factores y que incorporan juicio

2,4 Dominar habilidades personales que contribuyan al éxito de la práctica de la ingeniería, entre ellas:

- Iniciativa y voluntad de aceptar riesgos
- Perseverancia y flexibilidad
- Pensamiento creativo
- Pensamiento crítico
- Conciencia de sí mismo
- Curiosidad y aprendizaje continuo
- Gestión del tiempo y recursos

2,5 Dominar habilidades profesionales que contribuyan al éxito de la práctica de la ingeniería, entre ellas:

- Ética profesional, integridad y responsabilidad
- Comportamiento profesional
- Planificación proactiva de su carrera
- Actualidad de conocimiento en el campo de la ingeniería

3. Habilidades interpersonales: trabajo en equipo y comunicación.

3,1 Liderar y trabajar en grupos

- Formación de equipos efectivos
- Capacidad de operación de equipos
- Identificar y desarrollar habilidades para el crecimiento y evolución del equipo
- Ejercer liderazgo de equipo y capacidad de dirección de equipos
- Capacidad de trabajar en distintos tipos de equipos y colaborar técnicamente con los otros miembros del equipo.

3,2 Comunicación efectiva

- Analizar situaciones y elegir estrategias comunicacionales
- Construir estructuras comunicacionales adecuadas
- Comunicación por escrito
- Comunicación por medio electrónico/multi media
- Comunicación por medio gráfico
- Comunicación en presentaciones orales

4. Concebir, diseñar, implementar y operar sistemas en empresas y contextos sociales.

4,1 Reconocer la importancia del contexto social en la práctica de la ingeniería Entender el rol y la responsabilidad de los ingenieros

- Comprender el impacto de la ingeniería en la sociedad
- Describir las regulaciones sociales sobre la ingeniería
- Describir el contexto histórico y cultural preponderantes
- Desarrollar una perspectiva global

4,2 Apreciar diferentes culturas empresariales y trabajar exitosamente en organizaciones

- Apreciar diferentes culturas empresariales
- Reconocer la estrategia empresarial, sus metas y sus sistemas de planificación
- Reconocer el emprendimiento técnico
- Trabajar exitosamente en organizaciones

4,3 Concebir y aplicar ingeniería a los sistemas

- Fijar las metas y requerimientos de un sistema
- Definir función, conceptos y arquitectura de un sistema
- Desarrollar modelos de sistema que permitan evaluarlo
- Gestionar proyectos de desarrollo

4,4 Diseñar sistemas complejos

- El proceso de diseño
- Explicar las fases de un proceso de diseño y los enfoques
- Uso de conocimiento técnico en el diseño
- Diseño de procesos de la Disciplina
- Diseño multidisciplinario
- Diseño de Procesos con múltiples objetivos

4,5 Implementar procesos de hardware y software y gestionar los procedimientos de implementación

- Diseñar el proceso de implementación
- Describir el proceso de fabricación del hardware
- Describir el proceso de implementación del software
- Describir la integración de hardware y software
- Probar, verificar, validar y/o certificar el proceso
- Gestión de la implementación

4,6 Operar sistemas complejos, procesar y gestionar operaciones

- Diseñar y optimizar operaciones
- Describir la capacitación en operaciones
- Funciones de soporte a lo largo del ciclo de vida del sistema (eg: mantención, logística, etc)
- Reconocer la evolución y los mejoramientos del sistema y su eliminación
- Gestión de Operaciones

APPENDIX E. The CDIO Syllabus (Chinese)

1 **技术知识和推理**	1.1 相关科学知识 （由具体专业确定） 1.2 核心工程基础知识 （由具体专业确定） 1.3 高级工程基础知识 （由具体专业确定）	
2个人能力、职业能力和素质	2.1工程推理和解决问题的能力	2.1.1 发现问题和系统的表述问题 2.1.2 建模 2.1.3 估计与定性分析 2.1.4 带有不确定性的分析 2.1.5 解决方法和建议
	2.2实验和发现知识	2.2.1 建立假设 2.2.2 查询印刷资料和电子文献 2.2.3 实验性的探索 2.2.4 假设检验与答辩
	2.3 系统思维	2.3.1 全方位思维 2.3.2 系统的显现和交互作用 2.3.3 确定主次与重点 2.3.4 解决问题时的妥协、判断和平衡
	2.4个人能力和态度	2.4.1 主动性与愿意承担风险 2.4.2 执着与变通 2.4.3 创造性思维 2.4.4 批判性思维 2.4.5 了解个人的知识、能力和态度 2.4.6 求知欲和终身学习 2.4.7 时间和资源的管理
	2.5职业能力和态度	2.5.1 职业道德、正直、责任感和负责任 2.5.2 职业行为 2.5.3 主动规划个人职业 2.5.4 与世界工程发展保持同步

3人际交往能力：团队工作和交流	3.1团队工作	3.1.1 组建有效的团队
		3.1.2 团队工作运行
		3.1.3 团队成长和演变
		3.1.4 领导能力
		3.1.5 形成技术团队
	3.2 交流	3.2.1 交流的策略
		3.2.2 交流的结构
		3.2.3 书面的交流
		3.2.4 电子及多媒体交流
		3.2.5 图表交流
		3.2.6 口头表达和人际交流
	3.3使用外语的交流	3.3.1 英语
		3.3.2 其他区域工业国的语言
		3.3.3 其他语言

4在企业和社会环境下构思、设计、实施、运行系统	4.1外部和社会背景环境	4.1.1 工程师的角色与责任 4.1.2 工程对社会的影响 4.1.3 社会对工程的规范 4.1.4 历史和文化背景环境 4.1.5 当代课题和价值观 4.1.6 发展全球观
	4.2企业与商业环境	4.2.1 重视不同的企业文化 4.2.2 企业战略、目标和规划 4.2.3 技术创业 4.2.4 成功地在一个组织中工作
	4.3系统的构思与工程化	4.3.1 设立系统目标和要求 4.3.2 定义功能、概念和结构 4.3.3 系统建模和确保目标实现 4.3.4 开发项目的管理
	4.4 设计	4.4.1 设计过程 4.4.2 设计过程的分段与方法 4.4.3 知识在设计中的利用 4.4.4 单学科设计 4.4.5 多学科设计 4.4.6 多目标设计（DFX）
	4.5 实施	4.5.1 设计实施过程 4.5.2 硬件制造过程 4.5.3 软件实现过程 4.5.4 硬、软件集成 4.5.5 测试、证实、验证和认证 4.5.6 实施过程的管理
	4.6 运行	4.6.1 运行的设计和优化 4.6.2 培训与操作 4.6.3 支持系统的生命周期 4.6.4 系统改进和演变 4.6.5 弃置与（产品或系统）生命终结问题 4.6.6 运行管理

APPENDIX F. The CDIO Syllabus (v. 2.0) and the CDIO+LE Syllabus

May 2009

With minor clarifications and additions, principally on Sustainability and National Standards,
Additions that make it the CDIO+EL Syllabus (Entrepreneurship, Leadership) in blue
Coordinated with UNESCO four pillars
Entrepreneurship and Leadership are added as part of the CDIO+EL Syllabus

1 DISCIPLINARY (SUBJECT-BASED) KNOWLEDGE AND REASONING (was TECHNICAL KNOWLEDGE AND REASONING) (UNESCO: Learning to know)
- 1.1. KNOWLEDGE OF UNDERLYING MATHEMATICS AND SCIENCES [a]
- 1.2. CORE ENGINEERING FUNDAMENTAL KNOWLEDGE [a]
- 1.3. ADVANCED ENGINEERING FUNDAMENTAL KNOWLEDGE, METHODS AND TOOLS [k]

2 PERSONAL AND PROFESSIONAL SKILLS AND ATTRIBUTES (UNESCO: Learning to be)
- 2.1. ANALYTICAL REASONING AND PROBLEM SOLVING (was ENGINEERING REASONING AND PROBLEM SOLVING) [e]
  - 2.1.1. Problem Identification and Formulation
  - 2.1.2. Modeling
  - 2.1.3. Estimation and Qualitative Analysis
  - 2.1.4. Analysis With Uncertainty
  - 2.1.5. Solution and Recommendation
- 2.2. EXPERIMENTATION, INVESTIGATION AND KNOWLEDGE DISCOVERY [b]
  - 2.2.1. Hypothesis Formulation
  - 2.2.2. Survey of Print and Electronic Literature
  - 2.2.3. Experimental Inquiry
  - 2.2.4. Hypothesis Test, and Defense

[Revise text one layer down to include the issues of human and social science research]
- 2.3. SYSTEM THINKING
  - 2.3.1. Thinking Holistically
  - 2.3.2. Emergence and Interactions in Systems
  - 2.3.3. Prioritization and Focus
  - 2.3.4. Trade-offs, Judgment and Balance in Resolution
- 2.4. CREATIVE AND CRITICAL THINKING, LEARNING AND PERSONAL RESOURCES (was PERSONAL SKILLS AND ATTITUTES)
  - 2.4.1. (Moved to 2.5.6)
  - 2.4.2. (Moved to 2.5.8 and 2.5.9)
  - 2.4.3. Creative Thinking
  - 2.4.4. Critical Thinking
  - 2.4.5. Self-awareness and Meta-cognition (was Awareness of One's Personal Knowledge, Skills, and Attitudes)
  - 2.4.6. Lifelong Learning and Educating Others [i] (was Curiosity and Lifelong Learning)
  - 2.4.7. Time and Resource Management
  - 2.4.8. Knowledge Integration (Ensembling)
- 2.5. ETHICS, PROFESSIONAL RESPONSIBILITY, EQUITY, AND OTHER CORE PERSONAL VALUES (was PROFESSIONAL SKILLS AND ATTITUDES)
  - 2.5.1. Ethics, Integrity and Social Responsibility [f] (was Ethics, Integrity, Responsibility and Accountability)
  - 2.5.2. Professional Behavior and Responsibility [f]
  - 2.5.3. Proactively Planning for One's Career
  - 2.5.4. Staying Current on the World of Engineering
  - 2.5.5. Equity and Diversity
  - 2.5.6. Initiative and the Willingness to Make Decisions in the Face of Uncertainty(moved from 2.4.1, was Initiative and Willingness to Take Risks)
  - 2.5.7. Responsibility, Urgency and Will to Deliver (moved from 2.4.2 was part of Perseverance and Flexibility, and 2.5.1 Professional Ethics, Integrity, Responsibility and Accountability)
  - 2.5.8. Resourcefulness and Flexibility (moved from 2.4.2 was part of Perseverance and Flexibility)
  - 2.5.9. Trust and Loyalty
  - 2.5.10. Vision and Intention in Life

3 INTERPERSONAL SKILLS: TEAMWORK AND COMMUNICATION (UNESCO: Learning to live together)

- 3.1. TEAMWORK [d]
  - 3.1.1. Forming Effective Teams
  - 3.1.2. Team Operation
  - 3.1.3. Team Growth and Evolution
  - 3.1.4. Team Leadership (was leadership)
  - 3.1.5. Technical and Multi-disciplinary Teaming (was Technical Teaming)
- 3.2. STRUCTURED COMMUNICATIONS [g] (was Communications)
  - 3.2.1. Communications Strategy
  - 3.2.2. Communications Structure
  - 3.2.3. Written Communication
  - 3.2.4. Electronic/Multimedia Communication
  - 3.2.5. Graphical Communication
  - 3.2.6. Oral Presentation (was Oral Presentation and Inter-Personal Communications)
- 3.3. COMMUNICATIONS IN A FOREIGN LANGUAGE
  - 3.3.1. Communications in English
  - 3.3.2. Communications in languages of regional industrial nations (was incorrectly “of the EU”)
  - 3.3.3. Communications in other languages (was incorrectly “outside the EU”)
- 3.4. INFORMAL COMMUNICATIONS: RELATING TO OTHERS
  - 3.4.1. Inquiry, Listening and Dialog
  - 3.4.2. Negotiation, Compromise and Conflict Resolution
  - 3.4.3. Advocacy
  - 3.4.4. Establishing Diverse Connections (Grouping)

4 CONCEIVING, DESIGNING, IMPLEMENTING, AND OPERATING SYSTEMS IN THE ENTERPRISE, SOCIETAL AND ENVIRONMENTAL CONTEXT – INNOVATION (UNESCO: Learning to do)

- 4.1. EXTERNAL, SOCIETAL, ECONOMIC AND ENVIRONMENTAL CONTEXT [h]
  - 4.1.1. Roles and Responsibility of Engineers
  - 4.1.2. The Impact of Engineering on Society and the Environment
  - 4.1.3. Society’s Regulation of Engineering
  - 4.1.4. The Historical and Cultural Context
  - 4.1.5. Contemporary Issues and Values [j]
  - 4.1.6. Developing a Global Perspective
  - 4.1.7. Sustainability and the need for sustainable development
- 4.2. ENTERPRISE AND BUSINESS CONTEXT
  - 4.2.1. Appreciating Different Enterprise Cultures
  - 4.2.2. Enterprise Stakeholders, Strategy and Goals (was Enterprise Strategy, Goals, and Planning)
  - 4.2.3. Technical Entrepreneurship (Expanded in 4.8 of the CDIO+LE Syllabus)
  - 4.2.4. Working in Organizations (successfully omitted)
  - 4.2.5. Engineering Project Finance and Economics (added, was in 4.2.2.)
  - 4.2.6. New Technology Development, Assessment and Infusion (added, was in 4.2.2)
- 4.3. CONCEIVING, SYSTEMS ENGINEERING AND MANAGEMENT (WAS CONCEIVING AND ENGINEERING SYSTEMS) [c]
  - 4.3.1. Understanding Needs and Setting Goals (was Setting System Goals and Requirements)
  - 4.3.2. Defining Function, Concept and Architecture
  - 4.3.3. Modeling of System and Insuring Goals Can Be Met
  - 4.3.4. System Engineering and Development Project Management (was Development Project Management)
- 4.4. DESIGNING [c]
  - 4.4.1. The Design Process
  - 4.4.2. The Design Process Phasing and Approaches
  - 4.4.3. Utilization of Knowledge in Design
  - 4.4.4. Disciplinary Design
  - 4.4.5. Multidisciplinary Design
  - 4.4.6. Design for Sustainability, Safety, Operability, Aesthetics and other Objectives (was Multi-Objective Design (DFX))
- 4.5. IMPLEMENTING [c]
  - 4.5.1. Designing a Sustainable Implementation Process (was Designing the Implementation Process)
  - 4.5.2. Hardware Manufacturing Process

4.5.3. Software Implementing Process
4.5.4. Hardware Software Integration
4.5.5. Test, Verification, Validation, and Certification
4.5.6. Implementation Management

4.6. OPERATING [c]

4.6.1. Designing and Optimizing Sustainable and Safe Operations (was Designing and Optimizing Operations)
4.6.2. Training and Operations
4.6.3. Supporting the System Lifecycle
4.6.4. System Improvement and Evolution
4.6.5. Disposal and Life-End Issues
4.6.6. Operations Management

4.7. LEADING ENGINEERING ENDEAVORS [in CDIO+EL Syllabus]

Engineering Leadership builds on factors already included above, including:

- **Core Personal Values and Character of Leadership** including topics in Ethics, Professional Responsibility, Equity, and Other Core Personal Values (2.5), and Self-Awareness and Meta-cognition (2.4.5), and Lifelong Learning and Educating Others (2.4.6)
- **Relating to Others**, including topics in Informal Communications (3.4) Teamwork (3.1) and Structured Communications (3.2), and potentially Communications in a Foreign Language (3.3)
- **Making Sense of Context**, including topics in External, Societal and Natural Context (4.1); Enterprise and Business Context (4.2) and System Thinking (2.3)

In addition there are several topics that constitute creating a **Purposeful Vision (Enterprising)**:

4.7.1. Thinking Creatively and Imagining Possibilities (which builds on and expands Creative Thinking 2.4.3)
4.7.2. Defining the Solution (which builds on and expands Understanding Needs and Setting Goals 4.3.1)
4.7.3. Creating New Solution Concepts (which builds on and expands 4.3.2 and 4.3.3)

And several topics that lead to **Realizing the Vision (Engineering)**

4.7.4. Building and Leading and Organization and Extended Organization (which builds on 4.2.4)
4.7.5. Planning and Managing a Project to Completion (which builds on 4.3.4)
4.7.6. Exercising Project/Solution Judgment
4.7.7. Innovation – the conception, design and introduction of new goods and services (which builds on 4.4)
4.7.8. Invention – the development of new devices, materials or processes that enable new goods and services
4.7.9. Implementation and Operation – the creation and operation of the goods and services that will delver value (which are the leadership of 4.5 and 4.6)

These last three items are in fact the leadership of the core processes of engineering: conceiving, designing, implementing and operating

4.8. ENGINEERING ENTREPRENEURSHIP [in CDIO+EL Syllabus]

Engineering Entrepreneurship includes by reference all of the aspects of Societal and Enterprise Context (4.1 and 4.2), all of the skills of Conceiving, Designing, Implementing and Operating (4.3 – 4.6) and all of the elements of Engineering Leadership (4.7). In addition, there are the Entrepreneurship specific skills:

4.8.1. Company Founding, Formulation and Organization
4.8.2. Business Plan Development
4.8.3. Company Capitalization and Finances
4.8.4. Innovative Product Marketing
4.8.5. Conceiving products and services around new technologies
4.8.6. The Innovation System, Networks, Infrastructure and Services
4.8.7. Building the Team and Initiating Engineering Processes (conceiving, designing, implementing and operating)
4.8.8. Managing Intellectual Property

Biographical Information

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